SWIFT CURRENT ROTATION STUDY AFTER 12 YEARS - YIELD, PROTEIN AND N UPTAKE

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This study was established in 1966 by the late Dr. W.S. Ferguson and Mr. C. Hank Anderson on Wood Mountain loam (Orthic Brown chernozem) on land that had been in a cereal cropping system since 1922.

The main objectives of the study were: to evaluate the influence of rotation length, summerfallow substitutes, and N and P fertilizers on cereal yields, grain protein, N uptake by the plant, soil water and nitrate-N distribution in the soil, and the potential economic returns from these rotations.

This first preliminary report will deal with yield and grain protein. Subsequent reports will deal with (i) soil and plant nitrogen, (ii) soil and plant P, (iii) soil moisture distribution in the profile, and (iv) the economic returns from the various rotations.

MATERIALS AND METHODS

Twelve rotations (Table 1) were located on an area consisting of three blocks (reps) separated by two 10 m wide grass roadways, and each block subdivided into three 40 m long sub-blocks which were also separated by two 10 m wide grass roadways (Fig. 1). Each sub-block contained nine rotation-year treatments on 10.5 m wide plots. Thus, each block was made up of 27 plots each 10.5 x 40 m^2 for a total of 81 rotation-year plots. One- (i.e., continuous), 2- and 3-year rotations were cycled on the assigned plots. Thus, every fourth year the year one of a 3-year rotation would return to the same plot. Table 1 shows a list of the rotations used during the first 12 years of the study.

Farm-sized machinery was used for all cultural operations and weed control was by a combination of cultural practices and by chemicals using recommended methods and rates.

A 5 m swath cut down the middle of each plot was combine harvested for grain yield and protein content.

Soil samples taken in the fall were used to determine the amount of fertilizer that was required for each plot. Phosphate fertilizer was applied as 11-48-0 with the seed and nitrogen as 33-0-0 broadcast prior to seeding. Table 2 shows a summary of fertilizer applied to the various rotations. Note that most crops grown on fallow rarely received any N fertilizer.

RESULTS

Yield

(a) Some questions and answers

Q1. What effect has N and P fertilizer had on the yield and protein of wheat grown in a 3-year F-wht-wht rotation?

(a) On wheat on fallow [compare Rot. 1-2 vs 2-2 (N)]
[compare Rot. 5-2 vs 2-2 (P)]

(b) On wheat on stubble [compare Rot. 1-3 vs 2-3 (N)]
[compare Rot. 5-3 vs 2-3 (P)]

Ans. Generally yields were decreased by the failure to fertilize with N or P whether we were dealing with wheat grown on fallow (Fig. 2, top) or wheat on stubble (Fig. 2, bottom). The loss of yield for wheat on fallow when N was not applied averaged almost 5% and was as great as 10% while for wheat on stubble the loss was 7 and 16%, respectively (Table 3). Failure to apply P was even more serious with average loss in yield of wheat on fallow being 12% and as much as 23% while for wheat grown on stubble the corresponding losses were 11 and 34%, respectively. The failure to obtain greater differences in response to P between fallow and stubble crops suggests that P mineralized during fallow is very small or is not assessed by bicarbonate-P.

There was no obvious effect of N or P fertilizer on grain protein of wheat grown on fallow or wheat grown on stubble in the 3-year rotation.

Q2. What effect has N fertilizer had on the yield and protein of wheat grown in a continuous wheat rotation? (Compare Rot. 12-1 vs 8-1).

Ans. Failure to apply N fertilizer at recommended rates to continuous wheat reduced yields in 10 of 12 years (Fig. 3); the average decrease was 10%, but was as high as 25%.

As with yield, protein was decreased in 8 of the 12 years; the average decrease was by 12% and was as great as 40%.

Q3. How have flax (Rot. 3-2) and rye (Rot. 4-2) yields fared compared to wheat (Rot. 2-2) yields?

Ans. Over the 12-year period flax yields averaged 38% of wheat yields while rye yields were 8% greater than wheat yields (Table 4). However, it appears that rye yields were substantially greater than wheat yields in the first 4 years, then this trend was reversed. Although there are some confounding differences due to fertilizer, the effect still appears real. I suspect that this could be a reflection of the well-known "lack of self-tolerance" of winter rye.

(b) Ranking the yields

The 12-year (crop-year) average wheat yields of the various rotations were ranked (Table 5). The best yields were obtained for wheat grown on fallow. Failure to apply N to wheat grown on fallow reduced yields, but failure to apply P to wheat on fallow reduced yields even more. Wheat grown on stubble in the 3-year F-crop-crop rotations (Rot. 1-3 to 5-3) outyielded the continuous type of cropping rotations (Rot. 6 to 10 and 12), except when no P was applied to the 3-year rotation (Rot. 5-3). The lowest yields were obtained when continuous wheat was grown without N application (Rot. 12-1). The results showed that, on Wood Mountain loam, even when adequate N and P were applied continuous wheat will, on the average, yield only 75% of the yield obtainable on fallow. It appears that P application is a must for cereal production. N application is imperative for continuous cropping and seems to be necessary if maximum yields are to be obtained on fallow.

Although the rotations that included fallow appear to be the best when considered on a crop-year basis, if one converts the yields to a farm basis the picture is reversed and yields are directly related to rotation length (Table 6). Of course, the bottom line is really which of these systems is the most economical rather than highest yielding and this analysis has not yet been made.

(c) Yield trends

Over the 12-year period trends generally followed a positive slope (Fig. 4), and was positively related to growing season rainfall ($r^2 = 0.63^{**}$) when 1970 was excluded. When the wettest growing season (1970) was included, the relationship (Fig. 4) was not nearly as good ($r^2 = 0.37^{**}$) indicating that rainfall distribution is perhaps as important or more important than amount of precipitation received (Table 7). Yield was not as closely related to June and July pan evaporation.

Protein

(a) Ranking grain protein

Protein concentration in the grain of the 2-year wheat on fallow rotation was highest as expected, but wheat following flax grown on fallow (F-Flx-Wht) also had a similar high protein in grain (Table 5). The latter was probably related to the relatively small amount of N that is taken up by the preceding flax crop (i.e., compared to the other crops used in this study) (Table 8). The treatment effects on protein in grain were not great (mostly $\leq$ 6% difference) with the exception of continuous wheat receiving no N fertilizer (Rot. 12-1, Table 5 and Fig. 5). Continuous wheat with no N applied had, on the average, 15% lower protein in the grain than did wheat grown on fallow (2-year rotation) (Table 5) and on the average it had 12% less protein than continuous wheat receiving N fertilizer (Fig. 3).

(b) Protein trends

In contrast to grain yield the trend in protein in the grain generally decreased with time (Fig. 5). A similar trend was observed and reported for the prairies by the Canadian Wheat Board (albeit with some concern) during this same period. At that time some scientists suggested that the cause of the decreasing protein was the rapid diminution of the N supplying power of our soils. Although the latter could be a contributing factor, it is worth noting that the grain crude protein trend was generally inversely related to yield (see Fig. 4 and 5), thus the protein decrease could have been caused by dilution due to yield increase. This hypothesis is supported by the direct relationship observed between yield and growing season rainfall; that is, the later years of the 1970's had better rainfall distribution than the earlier years, thus inducing greater yields and causing dilution of the N taken up by the crop. A secondary factor might be that the greater rainfall facilitated leaching losses of NO_3-N in May-June period, thus reducing plant available N and consequently protein.

SUMMARY

A preliminary report on the yield and protein content results based on the first 12 years of a rotation study carried out on Wood Mountain loam at Swift Current was presented. Twelve feasible rotations including continuous cropping, 2-year wheat-fallow, and 3-year crop-fallow rotations with various N and P fertilizer treatments were employed. Other facets of the study such as soil mineral N distribution and soil water use and distribution, economics, and energetics were not reported at this time.

Some observations made were:

- On a crop-year basis the yield of wheat grown on summerfallow in 2-year fallow-wheat, or 3-year fallow-wheat-wheat rotations was greater than yields of wheat grown on stubble.

- When wheat was grown in continuous cropping rotations, and even when nitrogen and phosphorus fertilizers were applied at the recommended rates, the continuous wheat yielded only 75% as much as wheat grown on fallow that was fertilized with nitrogen and phosphorus.
- In a 3-year fallow-wheat-wheat rotation, yields of wheat grown on fallow were decreased by an average 5% by failure to fertilize with nitrogen at recommended rates and the loss in yield was as great as 10%. Failure to apply nitrogen fertilizer to the stubble crop resulted in an average decrease of 7% and was as great as 16%.
- Failure to apply phosphorus to wheat grown on fallow in a 3-year rotation was even more serious than failure to apply nitrogen; the average loss in yield was 12% and the loss could be as great as 23%. For wheat grown on stubble, failure to apply phosphorus resulted in an average loss in yield of 12%, but losses as high as 34% were observed.
- When nitrogen fertilizer was not applied to wheat grown in a continuous cropping rotation yields were decreased in 10 of the 12 years. The average decrease was 10% and the greatest decrease 25%.

The above findings were derived on a crop-year basis. They do not take into account the fact that on the farm a fallow year means a year of lost production. If we make our calculations on the basis of a per hectare of crop rotation, then we find that the picture is reversed. The continuous rotations give much greater total production than do the shorter rotations that include fallow. For example, continuous wheat produced 1394 kg/ha/yr, that is, 53% more than fallow-wheat.

Grain protein was also highest for the wheat on fallow rotations and lowest for continuous wheat with no N applied (the latter was 15% lower than wheat grown on fallow). Wheat grown on flax stubble of a fallow-flax-wheat rotation (N and P applied as required) produced as high a protein as wheat grown on fallow, perhaps because the flax uses little soil N.

Grain protein declined with time. It was suggested that this was not necessarily due to declining ability of the soil to supply the plant with N. Instead it was due to a dilution effect resulting from a trend towards an increase in yield that was correlated to growing season rainfall.

Table 1. Crop Rotations and Treatments

Rot. No.	Rotations	Comments
1	+(Fallow)-wheat-(wheat)	P applied as required but no N applied
2	Fallow-wheat-(wheat)	N and P applied as required
3	Fallow-flax-(wheat)	N and P applied as required
4	Fallow-(fall rye)-wheat	N and P applied as required
5	Fallow-wheat-wheat	N applied as required, no P applied
6	(Oat hay)-(wheat)-wheat	N and P applied as required; oats cut for hay at soft dough stage
7	Flax-wheat-wheat	N and P applied as required
8	(Continuous wheat)	N and P applied as required
9	Continuous wheat	[fallow if less than 60 cm moist soil at seeding time.] It was seeded every year until 1979. N and P applied as required.
10	Continuous wheat	[fallow if grassy weeds become a problem - weeds were controlled by chemicals - cropped every year until 1979]. N andP applied as required.
11	Fallow-(wheat)	N and P applied as required
12	(Continuous wheat)	P applied as required, no N applied

+ Special plots indicated by (   )

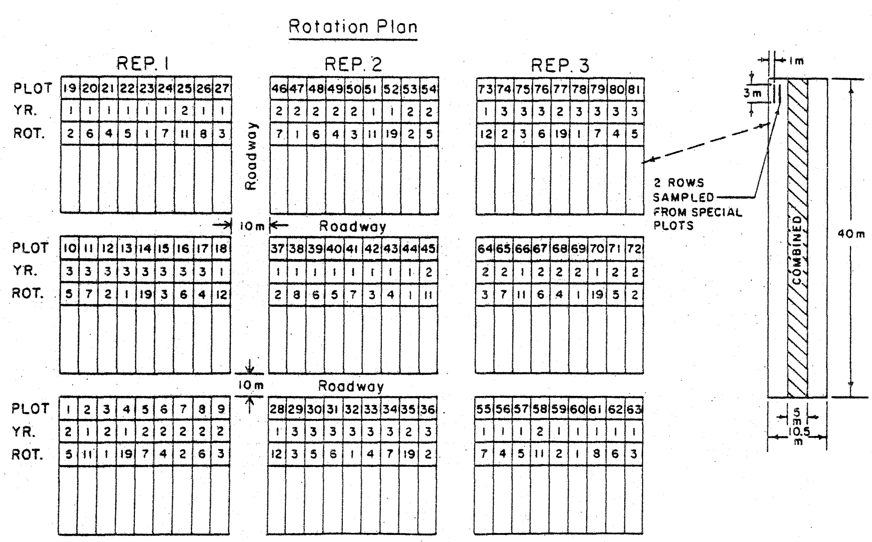

Fig. 1. Rotation Plan

Table 2. Average Nitrogen Applied+ Per Rotation-Year (kg/ha)

Rotation	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
2-2	0	13	0	0	11	0	0	0	0	0	0	6
2-3	34	6	13	8	25	22	6	0	17	6	34	0
3-2	0	20	0	0	11	0	0	0	0	0	0	0
3-3	34	0	25	6	28	11	0	6	6	0	45	0
4-2	0	0	0	0	0	0	0	0	0	0	0	0
4-3	34	28	30	6	20	22	0	0	20	11	0	22
5-2	22	11	0	0	0	0	0	0	0	0	0	11
5-3	34	20	6	0	14	6	0	0	17	6	22	17
6-1	34	17	0	14	30	17	17	0	6	17	45	50
6-2	34	0	0	19	30	11	11	11	34	22	37	50
6-3	34	6	8	20	30	22	6	6	22	6	39	45
7-1	34	11	17	6	30	0	6	0	22	11	50	22
7-2	34	22	15	0	28	17	0	11	17	34	45	45
7-3	34	15	9	6	8	22	0	6	11	11	17	45
8-1	34	25	15	6	28	6	6	17	28	22	50	50
9-1	34	15	15	13	31	0	6	11	28	17	50	50
10-1	34	6	20	11	30	28	6	17	28	17	45	50
11-2	0	0	0	0	11	0	0	0	0	0	0	6

+ All rotations received P fertilizer as indicated by soil test at a rate of 45 kg/ha of 11-48-0 unless the treatment dictated otherwise.

Table 3. Loss in yield when N and P were not applied in 3-yr F-wht-wht rotations

12-yr Av & range	Wheat on Fallow		Wheat on Wheat Stubble	
	No N	No P	No N	No P
	% loss in yield compared to treatment with N and P applied			
Average	4.5	12.0	7.2	11.2
Max.	10.2	23.1	15.9	34.2
Min.	0.0	4.5	0.0	1.3

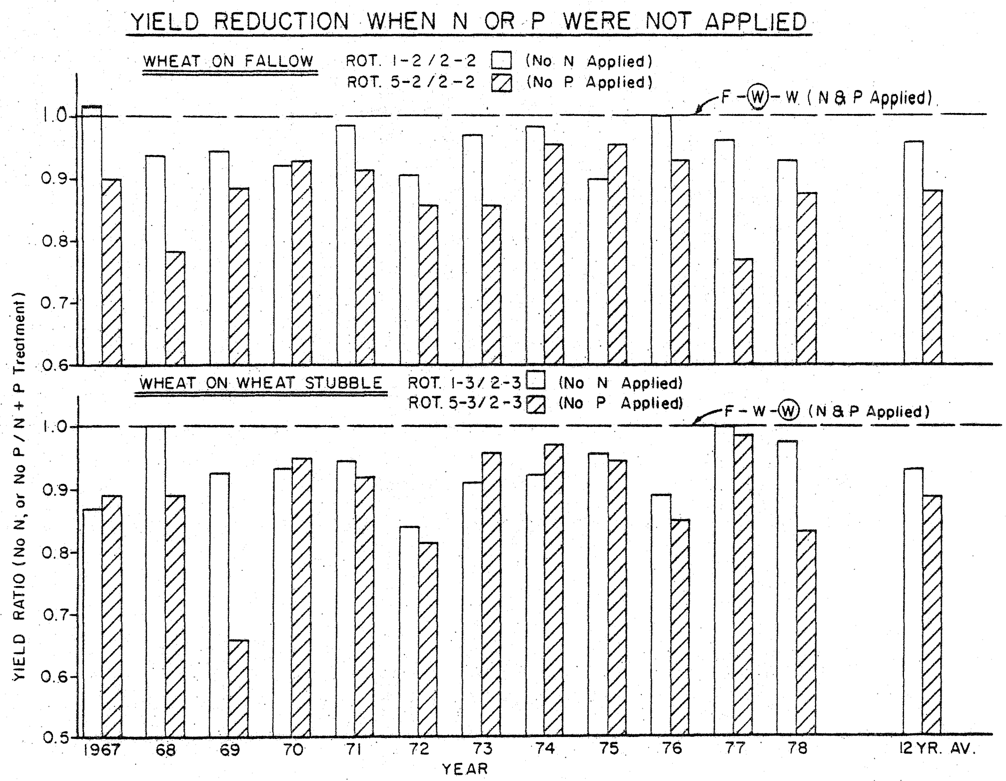

Fig. 2. Yield reduction when N or P were not applied

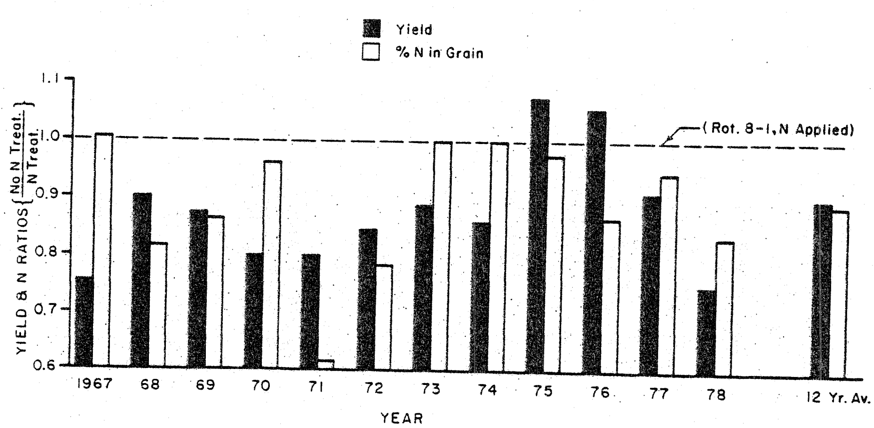

Fig. 3. Effect of N fertilizer on yield and protein of continuous wheat (Rot. 12-1 vs 8-1)

Table 4. How have flax (Rot. 3-2) and rye (Rot. 4-2) yields fared compared to wheat (Rot. 2-2) yields during the 12-yr period

Year	Yield Rot. 2-2 (kg/ha)	Yield ratio		Fertilizer N applied (kg/ha)		
		3-2/2-2	4-2/2-2	Rot. 2-2	3-2	4-2
1967	1260	0.39	1.39	0	0	11
1968	1430	0.38	1.19	13	20	9
1969	1915	0.35	2.14	0	0	9
1970	1401	0.87	1.51	0	0	6
1971	1904	0.35	0.96	11	11	11
1972	1833	0.26	0.54	0	0	11
1973	1199	0.40	0.87	0	0	0
1974	2115	0.30	0.55	0	0	0
1975	1845	0.32	0.77	0	0	9
1976	2607	0.27	-**	0	0	6
1977	3109	0.51	0.34*	0	0	0
1978	1733	0.28	1.59	6	0	0
Average	1863	0.38	1.08			

** Crop failure due to grasshoppers

* partial loss of stand due to grasshoppers

Table 5. 12-yr mean yield and protein of wheat in each crop year "marked" rotations

Rotation-yr no.	Rotation*	Fertilizer N	Fertilizer P	Yield/crop yr (kg/ha)	% of Check	Protein (%)	% of Check
11-2	F-W (check)	√	√	1818	100	16.2	100
2-2	F-W-W	√	√	1863	103	15.8	98
1-2	F-W-W	0	√	1782	98	15.8	98
5-2	F-W-W	√	0	1642	90	15.9	98
2-3	F-W-W	√	√	1453	80	15.7	97
1-3	F-W-W	0	√	1348	74	15.5	96
5-3	F-W-W	√	0	1290	71	15.6	96
4-3	F-Ry-W	√	√	1501	83	15.3	94
3-3	F-Flx-W	√	√	1484	82	16.2	100
8,9, 10-1	Contin. W	√	√	1394	77	15.3	95
12-1	Contin. W	0	√	1236	68	13.8	85
6-3	O (Hay)-W-W	√	√	1386	76	15.4	95
7-3	Flx-W-W	√	√	1336	73	15.3	94
6-2	O (Hay)-W-W	√	√	1407	77	15.5	96
7-2	Flx-W-W	√	√	1273	70	15.7	97

Table 6. Total yield for wheat rotations over the first 12 years

Rotation	Fertilizer N	Fertilizer P	12 year total+ yield (kg/ha)	% of Check	Av. annual yield (kg/ha) on farm basis
F-W (check)	√	√	10,908	100	909
F-W-W	√	√	13,264	122	1105
F-W-W	0	√	12,520	115	1043
F-W-W	√	0	11,728	108	977
Cont. W	√	√	16,728	153	1394
Cont. W	0	√	14,832	136	1236

\+ e.g., F-W = crop-yr yield x 6; F-W-W = (yield of yr 2 + yr 3) x 4; continuous wheat = yield x 12

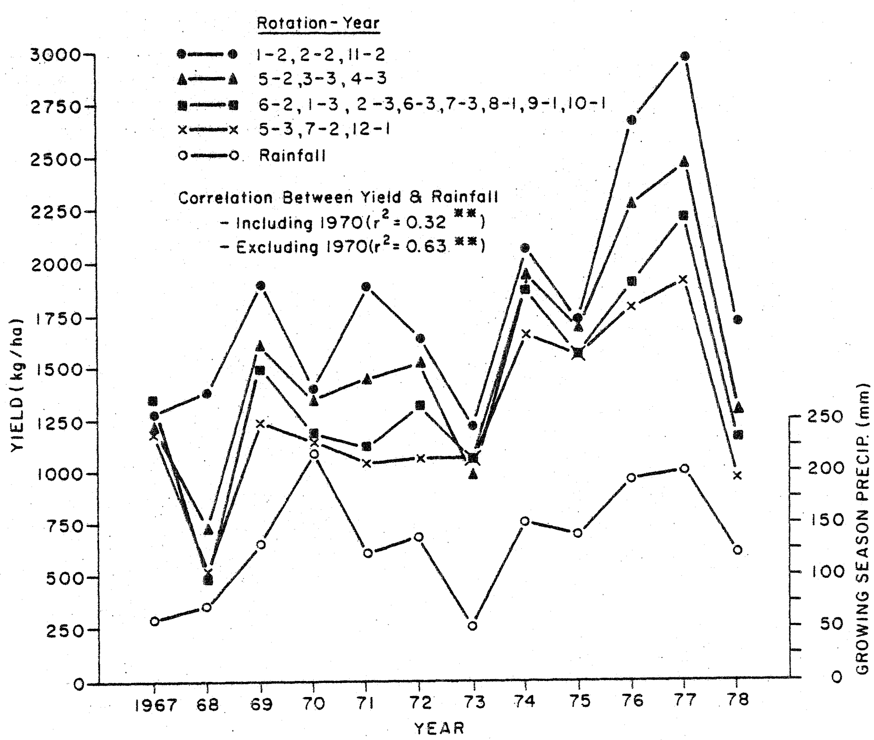

Fig. 4. Yield trends

Table 7. Growing Season Weather Conditions

	Precipitation			Pan Evaporation			Mean Max. Temp.		
	May	June (mm)	July	May	June (mm)	July	May	June (°C)	July
1967	36.1	16.0	4.8	189	237	364	15.3	20.6	27.3
1968	20.3	22.9	20.3	245	246	310	15.9	20.4	25.9
1969	23.4	29.2	80.0	215	233	229	17.2	20.4	23.4
1970	22.6	185.9	27.2	194	252	222	15.4	24.2	24.9
1971	10.7	68.1	42.4	267	219	265	19.6	21.6	23.7
1972	54.1	55.9	26.4	219	281	207	18.7	23.2	21.6
1973	9.7	23.1	17.5	222	283	334	17.8	22.8	26.3
1974	84.8	21.1	44.4	133	283	320	12.9	23.2	25.8
1975	37.6	61.0	37.6	138	218	313	14.4	20.2	27.6
1976	22.9	122.2	44.5	320	216	256	21.1	19.4	24.4
1977	101.9	24.4	72.4	201	253	240	19.1	23.1	24.1
1978	45.2	63.2	10.7	187	243	257	17.4	23.5	25.0